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A framework for successful new product development

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Abstract:

Purpose: The purpose of this paper is to propose a framework of critical success factors, metrics, and tools and techniques for implementing metrics for each stage of the new product development (NPD) process.

Design/methodology/approach: To achieve this objective, a literature review was undertaken to investigate decades of studies on NPD success and how it can be achieved. These studies were scanned for common factors for firms that enjoyed success of new products on the market.

Findings: The paper summarizes NPD success factors, suggests metrics that should be used to measure these factors, and proposes tools and techniques to make use of these metrics. This was done for each stage of the NPD process, and brought together in a framework that the authors propose should be followed for complex NPD projects.

Research limitations/implications: Several different research directions could provide additional useful information both to firms finding critical success factors (CSF) and measuring product development success as well as to academics performing research in this area. The main research opportunity exists in implementing or testing the proposed framework.

Practical implications: The framework can be followed by managers of complex NPD projects to ensure success.

Originality/value: While many studies have been conducted on critical success factors for NPD, these studies tend to be fragmented and focus on one or a few phases of the NPD process. To the authors' knowledge, this is the first time a framework that synthesizes these studies into a single framework.

Keywords: new product development, critical success factors, metrics, tools and techniques

1 Introduction

The new product development (NPD) literature emphasizes the importance of introducing new products on the market for continuing business success. Its contribution to the growth of the companies, its influence on profit performance, and its role as a key factor in business planning have been well documented (Booz, Allen & Hamilton, 1982; Crawford, 1987; Urban & Hauser, 1993; Cooper, 2001; Ulrich & Eppinger, 2011). New products are responsible for employment, economic growth, technological progress, and high standards of living. Therefore, the study of NPD and the processes through which they emerge is important.

In the last few decades, the number of new product introductions increased dramatically as the industry became more aware of the importance of new products to business. Correspondingly, managing the NPD process has become a challenge for firms as it requires extensive financial and human resources and is time sensitive. The harsh realities are that the majority of new products never make it to market and those that do face a failure rate somewhere in order of 25 to 45 percent (Crawford, 1987; Cooper, 2001). For every seven new product ideas, about four enter development, one and a half are launched, and only one succeeds (Booz, Allen & Hamilton, 1982). Despite the extensive research on how to achieve success in NPD, firms continue to deliver products that fail and therefore NPD ranks among the riskiest and most confusing tasks for most companies. As the number of dollars invested in NPD goes up, the pressure to maximize the return on those investments also goes up. It becomes worse as an estimated 46 percent of resources allocated to NPD are spent on products that are canceled or fail to yield an adequate financial return.

In this paper, we propose a framework that identifies the critical success factors (CSF) for each phase in the NPD process, metrics to measure them, and the tools

and techniques that can be used to evaluate each metric. Our study is based on an extensive review of the NPD literature. The paper is presented as follows. In the next section, we discuss the NPD process, followed by a discussion of critical success factors and metrics. Our framework is then described in detail, and we conclude with a discussion of our work.

2 New product development

The NPD process consists of the activities carried out by firms when developing and launching new products. A new product that is introduced on the market evolves over a sequence of stages, beginning with an initial product concept or idea that is evaluated, developed, tested and launched on the market (Booz, Allen & Hamilton, 1982). This sequence of activities can also be viewed as a series of information gathering and evaluation stages. In effect, as the new product evolves, management becomes increasingly more knowledgeable (or less uncertain) about the product and can assess and reassess its initial decision to undertake development or launch. Following this process of information gathering and evaluation can lead to improved new product decisions on the part of firms by limiting the level of risk and minimizing the resources committed to products that eventually fail. The NPD process differs from industry to industry and from firm to firm. Indeed it should be adapted to each firm in order to meet specific company resources and needs (Booz, Allen & Hamilton, 1982).

Many researchers have tried to develop a model that captures the relevant stages of the NPD process (Ulrich & Eppinger, 2011; Wind, 2001; Cooper, 2001; Crawford, 1987; Scheuing, 1974). A number of detailed NPD models have been developed over the years, the best known of which is the Booz, Allen and Hamilton (1982) model, shown if Figure 1, also known as the BAH model, which underlies most other NPD systems that have been put forward. This widely recognized model appears to encompass all of the basic stages of models found in the literature. It is based on extensive surveys, in depth interviews, and case studies and, as such, appears to be a fairly good representation of prevailing practices in industry.

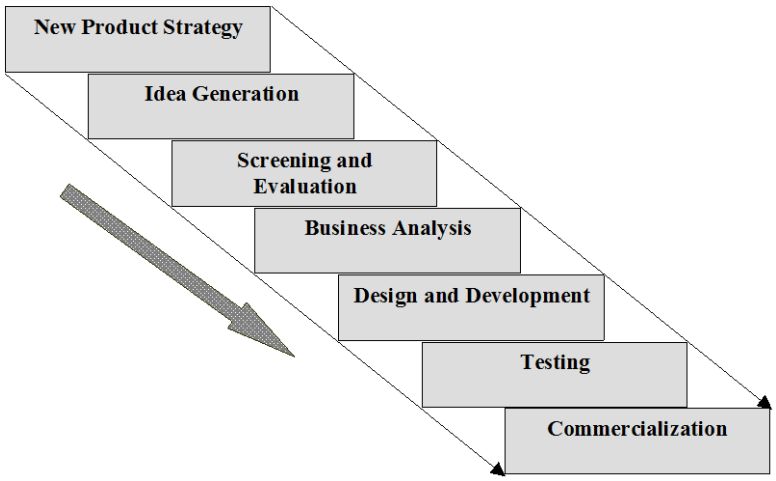

Figure 1. Stages of New Product Development (NPD) (Booz, Allen & Hamilton, 1982)

The stages of the model are as follows:

- *New Product Strategy*: Links the NPD process to company objectives and provides focus for idea/concept generation and guidelines for establishing screening criteria.
- *Idea generation*: Searches for product ideas that meet company objectives.
- *Screening*: Comprises of an initial analysis to determine which ideas are pertinent and merit more detailed study.
- *Business Analysis:* Further evaluates the ideas on the basis of quantitative factors, such as profits, Return-on-investment (ROI), and sales volume.
- *Development*: Turns an idea on paper into a product that is demonstrable and producible.
- *Testing*: Conducts commercial experiments necessary to verify earlier business judgments.
- *Commercialization*: Launches products.

Booz, Allen and Hamilton (1982) found that companies that have successfully launched new products are more likely to have some kind of formal NPD process and that they generally pass through all of the above stages. Our framework is based on the BAH model, however, we exclude the commercialization stage; while

this stage represents an important area of concern, our study deals with the pre-commercialization stages of the NPD process.

2.1 Critical success factors

Over the last two decades, several studies have examined the determinants of NPD success and identified many factors that distinguish successful products from unsuccessful ones. Factors that are necessary and guarantee commercial success are termed as critical success factors (CSF): it is imperative to reflect on how one can benefit from each and how one can translate each into an operational aspect of the NPD process. Daniel (1961) and Rockart (1979) proposed that organizations need to identify factors that are critical to the success of that organization, and they suggested that the failure to achieve goals associated with those factors would result in organizational failure. In fact, it is even suggested that NPD itself is a CSF for many organizations. Given that this is now a well-known fact, the idea is to determine what factors in NPD are essential for success, and how to measure the extent of this success. The challenge is to design a process for successful product innovation - a process whereby new product projects can move quickly and effectively from the idea stage to a successful launch and beyond.

2.2 Metrics

A metric tracks performance and allows a firm to measure the impact of process improvement over time. Metrics can play an important role in helping companies to enhance their NPD efforts and are important for at least three reasons. First, metrics document the value of NPD and are used to justify investments in this fundamental, long term, and risky venture. Second, good metrics enable Chief Executive Officers and Chief Technical Officers to evaluate people, objectives, programs, and projects in order to allocate resources effectively. Third, metrics affect behavior. When scientists, engineers, managers, and other NPD employees are evaluated on specific metrics, they often make decisions, take actions, and otherwise alter their behavior in order to improve the metrics. The right metrics align employees' goals with those of the corporation; wrong metrics are counterproductive and lead to narrow, short-term, risk-avoiding decisions and actions.

Any metric that might be applied to NPD will often focus on one function or another or on the entire NPD process. But no one function is the sole contributor to the process that produces new products. A metric for the productivity of the R&D organization, for example, may show constant improvement. In spite of this

improvement, however, there may be no improvement in the rate at which new products reach the market (Beliveau et al., 2002). What is important to measure is the effectiveness of the stages of NPD process in an interdependent fashion. A lack of useful metrics is undoubtedly one reason that the success rate of NPD has not improved appreciably over the past 40 years Crawford (1979, 1992). If companies had reliable metrics to gauge their performance, then specific problem areas could be addressed and managers might see the same improvement in their NPD efforts that they come to expect from their quantifiable total quality management programs (Lynn & Reilly, 2000).

3 Critical success factors and metrics for stages of the NPD process

In what follows, each stage of the NPD process and its respective CSFs, metrics, and tools and techniques for measuring progress are explained in detail.

3.1 New Product Strategy

Prior to commencing an NPD project, companies must set objectives and devise a clear new product strategy (NPS) to meet them (Wind, 1982). The purpose of this stage is to provide guidance for the new product effort. It identifies the strategic business requirements that the new product should comply with, and these are derived from the corporate objectives and strategy of the firm as a whole. These business requirements assign roles to be played by the new products, which in turn are influenced by the needs of the industry (Booz, Allen & Hamilton, 1982).

CSFs for NPS

A firms' strategy should provide a clear understanding of the goals or objectives for the company's new product program, and should indicate the return-on-investment (ROI) expected such that the contribution of new products to corporate goals is well-understood. Furthermore, clearly defined arenas, i.e., specified areas of strategic focus, such as products, markets, or technologies, are needed to give direction to the firm's total new product program.

The problem at this stage is not only one of developing a clear strategy but also its implementation, i.e., translating the strategy into terms that everyone understands to bring focus to day-to-day actions, and communicating the strategy with other members in the organization. Prior research suggests that companies that recognize the importance of interventional coordination and effectively sharing an NPS across departments will have more successful new products (Cooper, 1999).

The role of new products in achieving company goals was clearly communicated to all in such firms. Thus, once a clear NPS is defined, the related confounding problem is communicating clearly the needs, requirements, resources, and plans for a new product effort - in essence, internalizing the strategy. This communication must take place in multiple forms; however, a well-documented plan and specification must serve as the foundation. In summary, the establishment and communication of a clear plan and a strategy for an NPD project is a key requisite for success. Businesses that have a well-articulated NPS fare much better than those lacking in this aspect and they have 32 percent higher NPD success rates, meet sales objectives 42 percent more often, and meet profits objectives 39 percent better (Cooper & Kleinschmidt, 1995).

Metrics for NPS

The return-on-investment (ROI) compares the company's yearly income with the investment in the asset. While the ROI is not too challenging, management should understand how the ROI benchmarks have been calculate so that relevant comparisons can be made for the project under evaluation. A company's ROI proves to be useful in setting the new product goals. This metric will help to determine if the cost to develop a new product exceeds the resulting benefit, or if the payback affects the corporate bottom line. The aim here is to compare the return expected to be received from the project with some pre-established requirement. This long-term metric set by the corporate objectives should be linked with the NPS.

Tools and techniques for NPS

The Balanced Scorecard (BSC) provides the instrument the firm needs to navigate to future competitive success (Kaplan & Norton, 1996). BSC translates an organization's strategy into a comprehensive set of performance measures that provides the framework for a strategic measurement and management system. The scorecard measures organizational performance drivers across four perspectives which provide its framework: financial, customers, internal business processes, and learning and growth. The objectives and the measures of the BSC are the collection of financial and non-financial performance measures; they are derived from a top-down process driven by the strategy of the business unit. The measures are balanced between the outcome measures - the results from past efforts - and the measures that drive future performance. The scorecard is balanced between objectives, easily quantified outcome measures and subjective performance drivers of the outcome measures. Organizations should use the scorecard as a strategic

management system, to manage their strategy over the long run and use it for the measurement focus of the scorecard to accomplish critical management processes, including communicating and linking strategic objectives and measures.

The BSC strategic objectives and measures are communicated throughout an organization via company newsletters, bulletin boards, videos, and even electronically through groupware and networked personal computers. The communication serves to signal to all employees of the critical objectives that must be accomplished if an organization's strategy is to succeed. Once all employees understand high-level objectives and measures, they can establish local objectives that support the business unit's global strategy.

The organizational communication and education program should not only be comprehensive but also periodic. Multiple communication tools can be used to launch the BSC program: executive announcement, videos, meetings, brochures and newsletters. This initial announcement should then be followed continually, by reporting scorecard and outcomes on bulletin boards, newsletters, groupware, and electronic networks. The design of such a program should begin by answering fundamental questions:

- What are the objectives of the communication strategy?
- Who are the target audiences?
- What is the key message for each audience?
- What are the appropriate media for each audience?
- What is the time frame for each stage of the communication strategy?
- How will top management know that the communication has been received?

The BSC links financial objectives to corporate strategy. The financial objectives serve as the focus for the objectives and measures in all the other scorecard perspectives. Every measure should culminate in improving financial performance. The scorecard starts with long-run financial objectives, and then links them to the sequence of actions that must be taken with financial processes, customers, internal processes, and finally employees and systems to deliver the desired long run economic performance. Many corporations, however, use identical financial objectives for all of their divisions and business units. This uniform approach is certainly feasible, consistent, and fair since all business unit managers will be

evaluated by the same metric, but different business units may follow quite different strategies.

3.2 Idea Generation

After setting a well-defined NPS for NPD, the idea generation stage begins, where the search for product ideas is made to meet company objectives. The idea generation concerns the birth, development, and maturation of a concrete idea. After defining the markets and segments based on the NPS it wishes to target, the firm must advance and nurture ideas wherever they occur to take advantage of the identified opportunities. As per the study done by Booz, Allen and Hamilton (1982), a firm has to generate at least seven ideas to generate one successful. Griffin (1997) says that an average of 100 ideas must be generated in order to yield 15.2 successes.

The main purpose of this stage is to create a number of different ideas from which the firm can select the most feasible and promising one(s). A greater likelihood of achieving success depends in part on the number of ideas generated. Firms that are effective at idea generation are those that do not focus solely on the first source to generate ideas, i.e. ideas that are originated from inside the firm, but that concentrate on all potential idea sources (Crawford, 1997). There is a multitude of sources as well as many different methods to generate ideas. The firm can derive new ideas from internal sources (i.e., employees, managers), external sources (i.e., customers, competitors, distributors, and suppliers), and from implementing formal research and development. Brainstorming, morphological, analysis and gap analysis are most commonly employed methods for generating ideas (Crawford, 1997). Customers can be an especially good place to start searching for new product ideas. The relatively high rate of success for product ideas originated from marketing personnel and customers (Souder, 1987).

CSF for Idea Generation

Customer focused idea generation is a CSF for this stage as per studies done by many researchers that show that a thorough understanding of customer's needs and wants is vital for new product success (Cooper, 1993; Crawford, 1987). Successful businesses and teams that drive winning new products have a dedication towards the voice of the customer. A strong customer involvement is necessary right from the idea generation stage. According to Souder's (1987) review of causes of NPD success and failure, he concluded that internally generated ideas had lower success rates then externally generated ideas. A relatively high rate of success is

achieved for project ideas that originated from marketing and customers as compared to ideas originating from R&D, suppliers, and management.

Metrics for Idea Generation

Metrics to track idea generation and enrichment include: number of ideas generated from the customer, number of ideas retrieved and enhanced from an idea portfolio, number of ideas generated over a period of time, and the value of ideas in idea bank. Among all of these metrics, the number of ideas generated from the customer is the most associated with the CSF of the idea generation stage. Firms must devote more resources to customer based idea generation activities, such as focus groups with customers; detailed, one-on-one interviews with customers; customer site visits, especially by technical people; the active solicitation of ideas from customers by the sales force; and the development of a relationship with lead users (Cooper, 1999).

Tools and techniques for Idea Generation

Understanding customer and market needs is a consistent theme for successful product development in studies by Song and Parry (1996) and Cooper (1999). There are many creativity and brainstorming techniques for enriching the idea stream. Effective methods for enriching the customer based idea stream utilize lead user methodology and ethnographic approaches.

The lead user methodology takes a different approach as compared to traditional approaches in which ideas are generated based on customer input and usually collect information on new product needs from a random or typical set of customers. The lead user process collects information about both needs and solutions from the leading edges of the target market and from markets facing similar problems in a more extreme form. The rich body of knowledge collected during this process continues to be useful during the remaining steps of product development and marketing (Lilien et al., 2002).

An ethnographic approach is a descriptive, qualitative market research methodology for studying the customer in relation to his or her environment (Cooper & Edgett, 2008). Researchers spend time in the field observing customers and their environment to acquire a deep understanding of customer's lifestyles or cultures as a basis for better understanding their needs and problems. In this approach, observation, interviews and the documentation are done for traces that people leave as they go about their everyday lives. Since it allows the use of

multiple converging perspectives - what people say, do, and use - it will always reveal more and provide greater insight. This deeper level of understanding is derived from customer to generate customer-based ideas.

3.3 Screening and Business Analysis

While the screening and business analysis are proposed as two different stages in the BAH model, we consider the two stages as one for simplicity of the proposed framework. In the screening stage, initial analysis is done based on the NPS, resources and competition, while in the business analysis stage, ideas are evaluated using quantitative performance criteria. After gathering enough new product ideas through various sources from the idea generation stage, which ideas to pursue will be selected based on the business value they bring. Making a good selection is critical to the future health and success of the business. The point is that product development costs rise substantially with each successive stage in the NPD process (Booz, Allen & Hamilton 1982). The ideas that have been classified as "Go" ideas must be screened further using criteria set up by top management (Cooper & de Brentani, 1984; de Brentani, 1986). These ideas must be described on a standard form that can be accessed by a new product committee. The committee then assesses each idea against a set of criteria, which verify the attractiveness and visibility of the idea as well as its fit with the company's strategy, objectives and resources. The ultimate result from screening and evaluation is a ranking of NPD proposals, such that the resources can be allocated to the projects that seem most promising (Crawford, 1997; Wind, 1982).

After screening, the business analysis is the detailed investigation stage that clearly defines the product and verifies the attractiveness of the project prior to heavy spending. According to Cooper's NewProd studies of new product, it was shown that weakness in the upfront activities seriously compromises the project performance. Inadequate market analysis and a lack of market research, moving directly from an idea into a full-fledged development effort, and failure to spend time and money on the up-front steps, are familiar themes in product failures. The quality of execution of the predevelopment steps is closely tied to the product's financial performance (Cooper, 1980).

In every successive stage of the NPD process, as estimates become more refined and accurate, companies should continue conducting financial evaluation throughout the NPD process, but at this stage it is critical. A review of a costs, potential sales and profit projections of the new product are undertaken in order to determine whether these factors satisfy the company's objectives or not. If a result

from this stage shows that the product meets the objectives, then the new product concept can move to the development stage. According to Griffin (1997) among the firms taking part in study, 75.6% developed formal financial objectives against which performance was measured. The final component of the business analysis stage is the action plan. A detailed plan of action is created for the next stage and tentative plans are developed for all subsequent stages. This critical stage opens the door to a significant commitment of resources and to a full-fledged development program based on financial analysis which forms the base for the CSF and its metrics proposed for this stage.

CSF for Screening and Business Analysis

Up-front homework is a CSF for the screening and business analysis stage as too many new product projects move from the idea stage right into development with little or no early preparation (Rosenau et al., 1996). The results of this approach are usually disastrous. Up-front homework includes activities such as financial analysis, undertaking thorough market and competitive analyses, research on the customer needs and wants, concept testing, and technical and operations feasibility assessments. Solid pre-development work drives up new product success rates significantly and is strongly correlated to financial performance. All of these activities lead to solid business analysis prior to beginning serious development work. Firms devote on average only seven percent of a project's funding and 16 percent of the person-days to these critical up-front homework activities, which is not enough to make a successful product according to the NewProd (1999) study. The conclusion is that more time and resources must be devoted to the activities that precede the design and development of the product.

As per a study done by Cooper et al. (2000), the most dominant method used by 40.4% of businesses for performance results is a financial approach, followed by strategic approaches and scoring models. Using financial methods, profitability, return, payback or economic value of the project are determined and projects are judged and rank-ordered on these criterion.

Metrics for Screening and Business Analysis

Financial or economic models treat project evaluation much like a conventional investment decision. The expected commercial value (ECV), net present value (NPV), internal rate of return (IRR), and the profitability index (PI), are metrics that are proposed as being most useful for measuring the success of the screening and business analysis stage. These metrics should be used to rate, rank order, and

ultimately select projects. All metrics have their own advantages and disadvantages. For example, the NPV method ignores probabilities and risk; it assumes that financial projections are accurate and financial goals are important. The ECV depends on extensive financial and other quantitative data. These metrics together give clearer details about the project's financial performance to help select the best project from the group.

Tools and techniques for Screening and Business Analysis

The financial methods of evaluation for the proposed metrics and how they measure the financial performance of each project are explained below.

The Expected Commercial Value (ECV) method seeks to maximize the value or commercial worth of the project, subject to certain budget constraints, and introduces the notion of risks and probabilities. The ECV method determines the value or commercial worth of each project to the corporation. The calculation of the ECV is based on a decision tree analysis and considers the future stream of earnings from the project, the probabilities of both commercial success and technical success, and both commercialization costs and development costs. Therefore, the ECV measures the value of the project in terms of its expected financial returns from the perspective of the company's overall commercial strategic objectives. In order to arrive at a prioritized list of projects, the ECV of each project is determined projects are rank ordered accordingly.

The net present value (NPV) criterion for evaluating proposed capital investments involves summing the present values of cash outflows required to support an investment with the present value of the cash inflows resulting from operations of the project. The inflows and outflows are discounted to present value using the firm's required rate of return for the project. If the NPV is positive, it means the project is expected to yield a return in excess of the required rate; if the NPV is zero, the yield is expected to exactly equal the required rate; if the NPV is negative, the yield is expected to be less than the required rate. Hence, only those projects that have a positive or zero NPV meet the criterion for acceptance.

The internal rate of return (IRR) is that rate which exactly equates the present value of the expected after-tax cash inflows with the present value of the after-tax cash outflows. Once the IRR of a project has been determined, it is a simple matter to compare it with the required rate of return to decide whether or not the project is acceptable. If the IRR equals or exceeds the required rate, the project is

acceptable. Ranking the projects is also a simple matter. Projects are ranked according to the IRRs: the project with the highest IRR is ranked first and so on.

The profitability index (PI) is the ratio of the present value of the after-tax cash inflows to the outflows. A ratio of one or greater indicates that the project in question has an expected yield equal to or greater than the discount rate. The profitability index is a measure of a project's profitability per dollar of investment. As a result, it is used to rank projects of varying costs and expected economic lives in order of their profitability. Projects are rank-ordered according to this productivity index in order to arrive at the preferred portfolio, with projects at the bottom of the list placed on hold. In order to ensure that project ideas are carefully screened, and that the business analysis is carefully carried out, these metrics are certain to help select projects so as to maximize the sum of the values of all active projects in the firm's pipeline in terms of business objectives.

3.4 Development

Once the results of the business case of the new product conform to company objectives, the new product team can move on to the development stage, which is made up of activities that range from prototype development to volume ramp up and test marketing. The interaction between the program and project manager is no longer one of selling or buying the concept, but rather one of bringing the product to market on time, within budget, and to the required specifications.

On average, one third of total NPD expenditures are committed during this stage with 40 percent of total NPD time (Cooper, 1999). In the development stage, business case plans are translated into concrete deliverables. What is critical for success at this stage to move through development to launch as quickly as possible and to ensure that the product prototype or final design does indeed meet customer requirements, which requires seeking customer input and feedback throughout the entire development stage. It is important to gain competitive advantage and to enjoy the product's revenues as soon as possible and it also minimizes the impact of a changing environment. Thus, as the product proceeds from one step of the development stage to the next, the new product team should reassess the market, position, product, and technology in order to increase chances of delivering a successful product (Cooper, 1993; Urban & Hauser, 1993). Marketing and R&D functions in particular should collaborate because, while marketing can express the needs of customers, R&D has the capacity of turning a product concept into an actual physical entity. Therefore they should work together to ensure the product meets customer requirements. Cross-functional teams are

widely used in companies to help in identifying and solving problems efficiently by coordination of resources and ideas. Customer input and feedback is a critical activity throughout development, both to ensure that the product is right and also to speed development toward a correctly defined target.

CSFs for Development

Development of new products often takes years, and much that is unexpected can occur during this time frame. The market may change partway through development, making the original estimates of market size and product acceptance invalid. Customer requirements may shift, rendering the original set of product specifications obsolete. Competitors may introduce similar products in the meantime, creating a less receptive market environment. These and other external changes mean the original product definition and justification are no longer valid.

Reducing development time is a vital competitive weapon and yields competitive advantage; it means that there is less likelihood that the market or competitive situation has changed by time the product reaches the market and it means a quicker realization of profits Cooper (1993, 1999, 2001). Companies that develop products quickly gain many advantages over their competitors: premium prices, valuable market information, leadership reputation with consumers, lower development costs, and accelerated learning (Cooper, 2001). Therefore, the goal of reducing the development time is critical. Most importantly, fast development minimizes the impact of a changing environment. If the development time can be reduced from eighteen months to nine, the odds of things changing are similarly greatly reduced that makes the need to reduce the time during the development stage. Most firms have reduced product development times over the past five years with the average reduction being about the one-third. In short, the challenge here is to shorten development time so as to minimize the chances that the development target has changed.

Seeking customer feedback is a vital activity throughout development stage, both to ensure that the product design is right and also to speed development toward a correctly defined target. The original voice-of-customer research that was done prior to development may not be enough to resolve all the design problems during development (Cooper, 1999). Customer feedback is perhaps the most certain way of seeking continual and honest customer input during the development phase. Seeking customer input should become an integral part of the design team to speed up and make development stage successful.

Metrics for Development

Development time is defined as the duration from the start to completion of the development stage, i.e., the length of time to develop a new product after passing business case stage to initial market sales. Precise definitions of the start and end point vary from one company to another, and may also vary from one project to another within the company. How quickly the team moves through this stage is critical for the reasons stated earlier, and as such, it is imperative that the team measures their progress according to time.

A cross-functional team is defined as a team consisting of representatives from the various functions involved in product development, usually including members from marketing, R&D, and operations (and perhaps others, such as purchasing, as needed). The most effective development teams also involve suppliers in the early stages of development, and frequently rely on suppliers for a large portion of the subsystem design (Clark & Fujimoto, 1988). Cross-functional teams have replaced a more functional approach in which each team relinquishes project responsibility to a down-stream function (e.g. the engineering team hands-off to the manufacturing team). This paradigm requires frequent communication between functions represented on the team and co-location greatly facilitates this process. Cross-functional teams are essential for timely development, improving design quality, and lowering development costs. Cross-functional integration that really matters occurs when individual design engineers work together with individual marketers or process engineers to solve joint problems in development. True cross-functional integration occurs at the working level. It rests on the foundation of tight linkages in time and in communication between individuals and groups working closely related problems. How these groups work together determines the extent and effectiveness of integration in the design and development of the product (Wheelwright & Clark, 1992).

Related to the above is the degree to which team members are committed, or dedicated, to the project. Since project team members' time commitments are typically spread across a number of projects at any one time because departmental managers are vying for team members' time, team members are often on and off development projects. This creates a discontinuity and increases development time. It is in this stage that it is crucial to have a team with dedicated team members. A dedicated, accountable team leader- that is, not doing too many other projects or other assignments at the same time, and held accountable for the result.

Parallel processing involves activities that are undertaken concurrently (rather than sequentially), thus more activities are undertaken in an elapsed period of time. The purpose is to achieve product designs that reflect customer wants as well as manufacturing capabilities and to do so in the shortest possible time. However, due to the need for prerequisite information, not all activities or phases in the NPD process can be overlapped with minimal risk. Therefore, the degree of parallelism must be measured to ensure minimal downstream risk.

The degree of design effort on real customer needs is a qualitative in-process metric which ensures as much as possible that the final design meets customer requirements. This requires seeking customer input and feedback throughout the entire development stage and thus the customer becomes an integral part of the design team to overcome technical problems that arise and that necessitate product design changes during the development stage. Customer needs and wants assessment must be a vital and ongoing activity throughout development, both to ensure that the product is designed right and also to speed development toward a correctly defined target.

Tools and techniques for Development

The literature review has shown that there exist a number of tools and techniques to reduce development times that are consistent with sound management practice.

Dynamic time to market is a tool which can be useful in predicting the end date of the said project as well as in tracking the progress of a project. It works in the following way: when a schedule prediction is made, the prediction date is plotted against the date the prediction was made. By assessing dynamic time to market, the team members will get an early warning of potential late delivery and appropriate action can usually be taken by the team to maintain schedule integrity. Thus projects are kept on schedule to achieve timely product development.

The degree of team cohesiveness gauges the growth of the team as a working group and it is a function of length of time that a team has worked together in a past or present project (Balakrishnan, 1998). It is the extent to which team members are attracted to the team and motivated to remain in it.

Overlapping means doing various activities in parallel rather than doing them sequentially. By overlapping activities, the cycle time, i.e. the total time taken to complete the product development from concept until the product reaches market, can be greatly reduced. Overlapping activities saves time due to 1) parallel

processing of activities, 2) better and more timely identification of design problems, and 3) improved communication earlier and throughout the team. This metric serves as an indicator of the degree of concurrency in the process. In general, the higher the number of overlapped activities, the higher the degree of concurrency and the shorter is the development time. A lower number of overlapped activities indicates a lower degree of concurrency in the process and may also indicate opportunities for improving the process to achieve objectives.

3.5 Testing

The purpose of this stage is to provide final and total validation of the entire project: the commercial viability of the product, its production, and its marketing (Cooper & Kleinshmidt, 1987). Design and testing go hand in hand, with testing being conducted throughout the development stage. Information obtained during testing is used in developing the product. This phase is extremely important in that it may dramatically decrease the chances of failure in launch, since it has the capacity of revealing flaws that could cause market failure (Urban & Hauser, 1993). Studies by Cooper (1998, 1999) show that a test phase that is customer oriented is the critical factor - whether it is done and how well it is executed - is significantly correlated with the new product success. Different types of testing, i.e. concept testing, prototype/development testing, and test marketing, should be conducted in this stage Cooper (1993, 1998, 2001). It should be noted, however, that testing should not be solely restricted to this stage; it must be conducted throughout the NPD process (Ulrich & Eppinger, 2011).

CSF for Testing

Product functionality is critical for the testing stage as the aim here is to see whether a product with the attributes called for has been produced. It must be proven that claimed attributes exist and the causes for missing attributes must be found.

Customer acceptance is critical for this stage to gauge whether the product is acceptable to the customer, to measure the customer's level of interest, liking, preferences, and intent to purchase, and to determine those benefits, attributes, and features of the product to which the customer responds. Not only must the product work right in the lab or development department, but, more importantly, it must also work right when the customer uses it. The product must excite and, indeed, delight the customer; who must find it not only acceptable but actually like

it better than what he or she is currently buying. In short, the customer reaction must be sufficiently positive so as to establish purchase intent.

Metrics for Testing

The performance of a product is how well the product achieves the functionality desired. Product performance is usually measured in such ways as testing physical features, perceptual features, functional modes, and perceived benefits. Feature is those aspects of an offering that create the benefits; they are typically a focal point of NPD. Perceived benefits are the best point in the needs continuum on which to focus conversations with customers because they represent customer-oriented perceptions but are still close enough to supplier-oriented features to permit that linkage to be made by the product developer. Validation and user testing techniques are used to gather data on product performance. These primary research techniques generate quantitative results. At this stage in the NPD process, these are the types of research results necessary to make final critical decisions and reduce the risk of possible failed launches.

Customer-perceived value is measured to determine whether the customer is willing to purchase the tested product or not and to gauge whether the product is acceptable to the customer. Important metrics for this stage are: perceived relative performance, customer satisfaction (Like/Dislike), and the preference score to determine the nature of the competitive situation. These are qualitative metrics, but are very important nonetheless to record the basic likes/dislikes of the customer early before the product gets launched into the market. Based on the qualitative data, managers can take action to make changes in the product.

Tools and techniques for Testing

Validation testing is of a product model that closely resembles the final product that will be manufactured and sold, and is often called system testing and usually takes place in-house. The purpose of the testing process is to ensure that all product performance requirements and design specifications have been met. The validation test is normally conducted late in the development process to ensure that all of the product design goals have been met. This includes usability, performance, and robustness. Validation tests normally aim to evaluate actual functionality and performance, as is expected in the production version and so activities should be performed in full. It is probable that the validation test is the first opportunity to evaluate all of the component elements of the product together, although elements may have been tested individually already. Thus, the product should be as near to

representing the final item as possible, including packaging, documentation and production processes. Also included within validation tests will be any formal evaluation required for certification, safety or legislative purposes.

Data from a validation test is likely to be quantitative, based on measurement of performance. Normally, this is carried out against some benchmark of expected performance or criteria set before. Usability issues may be scored in terms of speed, accuracy or rate of use, but should always be quantified. Issues such as desirability may be measured in terms of preference or user ranking. Data should also be formally recorded, with any failures to comply with expected performance logged and appropriate corrective action determined.

User and field testing is performed by real users or customers, and in some cases, this testing must precede product shipment. This is not to be confused with marketing customer testing, where certain strategies regarding sale and marketing of the product are explored. The purpose of testing is to understand how the product performs in the end-user environment. Customer based testing is indeed complex, and there is no way it can be simulated in laboratories, where use is isolated from users' mistakes, competitive trashing of the concept, and objections by those in the user firm or family whose work or life is disrupted by the change. Products that are entirely new to the market should receive beta testing because there is no base of data on which to judge customer acceptance.

Test protocols are produced by the company and can range from rigorous to nonexistent. In the first case, the developer closely monitors and follows up the beta test with in-house staff or contracted staff from a specialty testing company. In the second case the developer may simply contact the customer by phone or has an group or individual contact to ask for opinions on the product. The test results attempt to confirm that the user feels the same toward the prototype as toward the verbal concept discussed earlier in the NPD stage. The results of the testing either confirm that the product meets its requirement or show the areas where the product is deficient, and is therefore a critical stage to be considered in the development process.

3.6 Framework of CSFs, metrics and tools and techniques for NPD

The CSFs, metrics, tools and techniques proposed for successful NPD discussed in the previous sections are all summarized in the framework proposed in Table 1.

Stage	Critical Success Factor	Metrics	Tools and Technique
New Product Strategy	Clear Strategy	Return on Investment	Financial Analysis
	Well Communicated Strategy	Degree of Communication	Balanced-scorecard as a Communication Tool
Idea Generation	Customer Focused Idea Generation	Number of Customer Focused Ideas Generated	Lead User Methodology
			Ethnographic Approach
Screening and Business Case	Up-Front Homework	Expected Commercial Value (ECV)	Financial Method of evaluation
		Net Present Value (NPV)	
		Internal Rate of Return (IRR)	
		Productivity Index (PI)	
Development	Speed	Development time	Team Cohesiveness
	Customer feedback	Degree of functional integration	Dynamic Time to Market
		Degree of team commitment	Degree of Parallelism
		Concurrency of activities	
		Degree of design effort on real customer priorities	
Testing	Product Functionality	Product Performance	Validation Testing
	Customer Acceptance	Customer-Perceived Value	User and Field Testing

Table 1. Critical Success Factors and Metrics for Stages of NPD Process

For each stage of the NPD process, the factors that are essential for success for each stage, metrics which can be used to measure the performance of those factors, and tools and techniques to implement the metrics are all detailed in the framework. As a preliminary proposed framework, we believe that any complex NPD project that follows this framework will have an increased chance at success.

4 Discussion and conclusions

New product success still remains the critical challenge for companies. Many companies are aware of the major role new products must play in their future and quest for prosperity: companies are constantly searching for ways to revitalize, restructure and redesign their NPD practices and processes for better results.

This framework proposes that to achieve success, NPD firms should have a clear and well communicated new product strategy. These firms should have well defined new product arenas along with long term trust, with clear goals. Successful businesses and teams of NPD have a dedication towards the voice of the customer. It is critical that firm should gather as many ideas as possible and a large number of these should come from customers so that the firm can be in a position to design and develop winning new products. Up-front homework prior to the initiation of product design and development is found to be a key factor in a firm's success. The

quality of execution of the predevelopment steps - initial screening, preliminary market and technical studies and business analysis - is closely tied to the products financial performance. Firms should try to shorten the development time so as to minimize the chances that the development and customer needs have changed when the product comes into the market. It is important to verify and validate product performance requirements and design specifications along with customer's acceptance before launching the product into the market via validation and user field testing.

This paper explored and analyzed the NPD process and attempted to identify ways in which firms can improve their performance when developing new products, mainly through the study of factors that are critical to success. These factors were identified through an extensive study of the practices and performance of successful firms presented in the NPD literature. The CSFs which have been described in the literature are generally defined for the overall development process, rather than specifically addressing each stage. To overcome this problem, this paper sought out CSFs for each stage of the process. Presumably, no other study to date has developed such a framework, which can be crucial for NPD success.

Several different research directions could provide additional useful information both to firms finding CSF and measuring product development success as well as to academics performing research in this area. The first research opportunity exists in implementing or testing the proposed framework. This would be useful to do over the longer term both among the community of NPD companies and through academic research to determine the impact of this research on both practice and research.

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